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Amphibian Surveys in the Cuyahoga Valley National Recreation Area

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Urban and suburban environments present difficult challenges to the persistence of amphibian populations. All of the suspected threats influencing amphibian decline may come into play (e.g., habitat degradation and fragmentation, acid precipitation, toxic substances, UV-B radiation, disease) and are likely to be particularly intense and multiple. Further, the potential for recolonization following local extinctions may be low due to isolation by surrounding roads, development, and otherwise unsuitable habitats. It therefore may be surprising that, in pockets of habitat such as parks and undeveloped areas, one still can find amphibians in urban and suburban settings.

Although it may be tempting to write off urban and suburban populations as doomed relicts, amphibian populations increasingly will become confined to these areas as human populations continue to grow, which has already occurred in much of North America. In addition, some effects of urbanization and industrialization are exported via air and water to surrounding, and often quite distant, "natural" areas. For reasons such as these, urban/suburban amphibian populations must not be ignored and indeed may serve as important tools in the development of amphibian conservation strategies. In this context, urban/suburban settings provide valuable research opportunities for investigating the effects of multiple stressors and the resilience of amphibian populations. Finally, most people encounter amphibians in urban/suburban habitats: treefrogs at the porch light or toads at the family picnic can provide a powerful argument for public support of amphibian conservation efforts.

We report here on the initial phases of a long-term amphibian monitoring program in the Cuyahoga Valley National Recreation Area (CVNRA) in northern Ohio. This unit of the National Park Service (NPS) contains 13,360 hectares in a north-to-south corridor along 35 kilometers of the Cuyahoga River and is located between two large urban and industrial centers, Cleveland and Akron (Fig. 18-1). As a National Recreation Area, the CVNRA affords the amphibians some degree of protection. That protection, however, has been in place only since 1974, when the park was established (Cockrell 1992). Further, the park boundaries are close to the two cities (13 kilometers from downtown Cleveland and 10 kilometers from downtown Akron). Residential suburbs, industrial development, heavily trafficked highways and roads, popular recreational/entertainment facilities, railways, and agricultural lands surround and enter the park. At its widest, the CVNRA is only 8.3 kilometers wide east-to-west, but the park is much narrower through much of its extent (as narrow as 0.5 kilometer at one point). The park hosts over a million visitors each year (Cockrell 1992), and use is heaviest in the warmer months during peak periods of amphibian activity. Clearly, there is great potential for multiple anthropogenic challenges to the amphibian populations of the CVNRA, including toxic substances from industrial, residential, or agricultural sources; acid precipitation; salt run-off from roadways; silting of streams due to upstream construction; disruption of migration routes by roads and development; draining of wetlands; clearing of habitat for commercial, residential, or recreational uses; killing by vehicles; and collecting and killing by

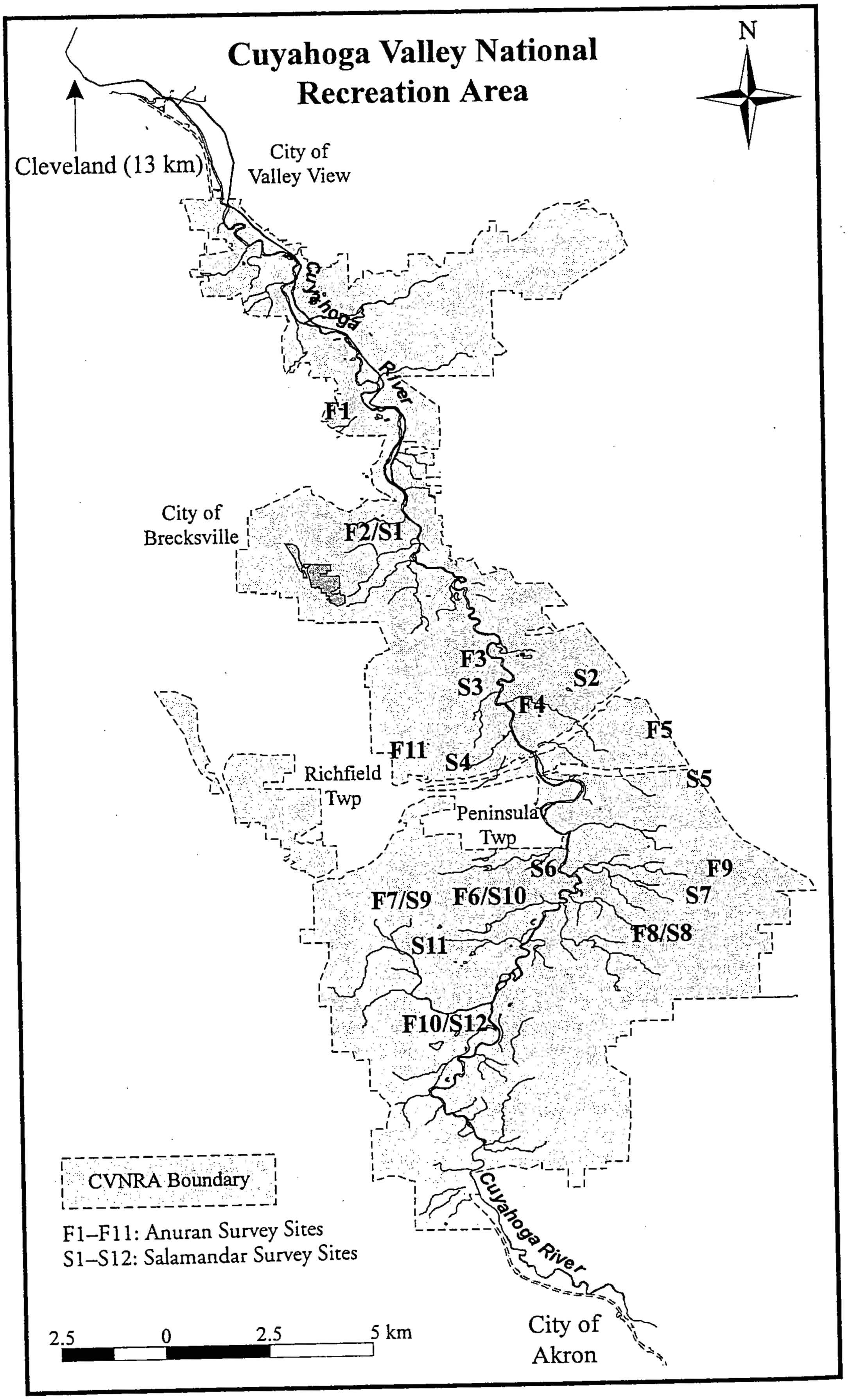
Cuyahoga Valley National Recreation Area
N
Cleveland (13 km)
City of Valley View
Cuyahoga River
F1
City of Brecksville
F2/S1
F3
S3
S2
F4
F5
F11
S4
Richfield Twp
S5
Peninsula Twp
S6
F9
F7/S9
F6/S10
S7
F8/S8
S11
F10/S12
CVNRA Boundary
F1–F11: Anuran Survey Sites
S1–S12: Salamandar Survey Sites
2.5
0
2.5
5 km
City of Akron

Figure 18-1. Locations surveyed for anurans and salamanders in the CVNRA.

visitors. However, there has been no investigation of the effects of these threats to amphibians in the CVNRA nor of the success of NPS management strategies for mitigating these effects.

The overall goals of this research are: (1) to conduct long-term monitoring of changes in amphibian abundance and species richness; (2) to identify and quantify important threats to amphibian populations; and (3) to investigate the physiological and demographic responses of amphibians in the CVNRA to those threats. We intend for this work to provide useful information for resource management in the park and for amphibian conservation efforts in general. Here, we report data from the first two years of the project, 1994 and 1995. The specific goals of this phase of the research were: (1) to initiate monitoring of abundance and species richness of anurans and of terrestrial and stream-side salamanders; (2) to search for patterns of decline, stasis, or increase through comparisons with historical records; (3) to identify species and/or localities with special problems; and (4) to validate automated call recording techniques for censusing anurans. With regard to the last goal, we present information on the acoustic performance of the automated recording device, the accuracy of the device for measuring population size, and the cost of the technique relative to traditional methods.

Methods and Materials

Performance Evaluation of the Automated Recording Device

Anuran sites were surveyed for calling anurans using two automated call recorders constructed according to the specifications of Peterson and Dorcas (1992, 1994). Peterson and Dorcas (1994) provide a components list and a circuitry schematic for the device. All components of the recording device are housed in a plastic toolbox (36 centimeters by 20 centimeters by 20 centimeters) and are powered by a twelve-volt motorcycle battery. The recorder consists of a timer that activates a tape recorder for a predetermined amount of time at preset intervals. At the onset of an interval, an internal microphone records the time from the voice clock. An external microphone then records sounds from the environment. The box was secured to a tree by a chain and lock and camouflaged by leaves and twigs to avoid vandalism. The external microphone was protected from rain by a camouflaged plastic cowling. A miniature temperature data logger (HOBO XT, Model HTEA-37+46, Onset Computer Corporation) was used to record environmental temperatures (air/water) every five minutes during the operation of the automated recorder.

We tested two aspects of performance of the automated recording device. First, we tested the effects of distance, habitat complexity (e.g., vegetation and topography), and species recorded on the quality of recordings. Second, we tested the utility of the device for estimating abundance of calling males.

Acoustic Performance. An experiment was conducted by placing the automated recording device at its normal recording location at Prucek Pond (F11, Fig. 18-1; Table 18-1) but with a person manually operating the recorder. A second person then played tape-recorded calls of four species (American toads [*Bufo americanus americanus*], eastern gray treefrogs [*Hyla versicolor*], northern spring peepers [*Pseudacris crucifer crucifer*], and western chorus frogs [*Pseudacris triseriata triseriata*]) at a fixed intensity (100 decibels at 1 meter, measured with a Bruel and Kjaer Integrating Sound Level Meter, Type 2225), at 10 meter intervals up to 50 meters from the automated device. This was repeated in four different directions (north, south, east, and west). The person at the recorder scored audibility of the playback from 0 to 4 (with 0 being inaudible and 4 being loud and clear). The same individual then listened to the recorded tape from the automated recorder and again assigned an audibility score. These scores were mapped on a topographical/vegetation map of the site to investigate patterns of audibility associated with habitat features. Variation in sensitivity of the device to calls of the four species was assessed with analysis of variance.

Population Density Estimation. One potentially valuable use of the automated recording device is to estimate population density of calling males. Population density of a species should be estimable by dividing the calling rate produced by a chorus of males by the average calling rate of individual males. Data from the recording device will provide the numerator of this ratio; the denominator, call rates of individuals, can be obtained by focal animal recordings or from the published literature.

One of us (G.V.) is conducting ecological studies of eastern gray treefrogs at Prucek Pond (F11, Fig. 18-1). These studies include nightly censusing of calling males during the breeding season and recording calls of every male in the chorus. Varhegyi has calculated the average

Table 18-1. Anuran survey sites at the CVNRA, brief descriptions of each site, and the species found during four separate surveys. Site identification numbers appear in parentheses following the site names (see Fig. 18-1). Abbreviations: Ba-*Bufo americanus americanus*; Hv-*Hyla versicolor*; Pc-*Pseudacris crucifer crucifer*; Pt-*Pseudacris triseriata triseriata*; Rca-*Rana catesbeiana*; Rcl-*Rana clamitans melanota*; Rp-*Rana palustris*; Rpi-*Rana pipiens*; Rs-*Rana sylvatica*.

		Species Found			
	Description	Walker 1946	Mazzer et al. 1984	Varhegyi et al. 1995	Varhegyi et al., this chapter
Periodically Surveyed Locations					
Fawn Pond (1)	Lowland, shallow pond, surrounded by tall grass	*	*	Ba, Hv, Pc, Rcl, Rp	Ba, Hv, Pc, Rcl
Brecksville (2)	Roadside vernal pools; pine, young birch, and oak trees	*	*	Ba, Hv, Pc, Pt, Rs	Ba, Pc, Pt
Snowville (3)	Some vernal pools, one deep pond, surrounded by tall grass	*	Ba, Hv, Rca, Rcl	Ba, Hv, Pc, Pt, Rca, Rcl, Rp Rpi, Rs	Ba, Hv, Pc, Pt, Rca, Rcl, Rp
Stanford (4)	Shallow pond near youth hostel	Ba**	Rp	Hv, Rp, Rcl	Hv, Pc, Rcl
Pipe Pond (5)	Small deep pond with steep banks, secondary growth forest	**	Rca, Rcl	Rca, Rcl	Rca, Rcl
Valley Picnic Area (6)	Small secluded upland pond, fed by stream, in secondary growth forest	**	Ba, Hv, Pt, Rcl	Pc, Rca, Rcl	Ba, Hv, Pc, Pt, Rca, Rcl
Hickory Pond (7)	Large upland pond, pine forest on one side and young trees and shrubs on other side	**	Ba, Rca	Ba, Pc, Pt, Rca, Rcl, Rs, Rcl, Rp	Ba, Pc, Pt, Rca
Kendall Lake (8)	Large lake (~5 acres), fed by stream, surrounded by secondary growth forest	**	Ba, Hv, Rca, Rcl, Rs	Hv, Pc, Rcl	Ba, Hv, Pc, Pt, Rca, Rcl
Happy Days (9)	Stream in a secondary growth forest near visitors center, deep ravines	Ba, Pc, Rp, Rs**	Rcl, Rp	Hv, Pc, Pt, Rcl, Rs	Ba, Pc
Indigo (10)	~2-acre lake surrounded by tall grass, shrubs, secondary growth forest, fed by stream	Hv, Pc, Pt, Rcl, Rp**	Rcl	Ba, Hv, Pc, Rca, Rcl	Ba, Hv, Pc, Pt, Rca, Rcl
Continuously Monitored Location					
Prucek (11)	Artificial pond, bordering farmland and hickory-maple forest	*	*	Ba, Hv, Pc, Pt, Rca, Rcl, Rp, Rs	Ba, Hv, Pc, Pt, Rca, Rcl, Rp

*Site not surveyed.
**Species found within 1 kilometer of the site.

call rate for males in this population to be eighteen calls per minute (n = 48). This value was used in the following equation to estimate density of calling males:

$$\text{estimated number of calling males} = \frac{\text{call rate of entire chorus (calls per minute)}}{\text{average call rate of individuals (calls per minute)}}$$

This estimate was compared to counts made by direct observation. We tested for correlation of these two population values by Pearson product-moment correlation.

Anuran Survey

Anuran survey sites were chosen to include as many potential breeding sites as possible and to resample previously surveyed locations (Fig. 18-1; Table 18-1). These sites were surveyed for calling anurans using two automated call recorders, previously described. We chose to record for twelve seconds every ten minutes, providing 144 intervals or thirty minutes of recording over a twenty-four-hour period. We found this setting to be efficient for sampling all species, even those that called for short periods. When tapes from the automated call recorder were played back in the laboratory, the time and the species calling were noted for each twelve-second interval. Acoustical evidence of weather conditions (e.g., wind sounds, the sound of rain on the plastic cowling) also was recorded. Temperature data from the data loggers were transferred to a personal computer and merged with the calling records.

The tapes were processed, as described above, by several of the authors (G.V., S.M.M., C.A.C.), by undergraduates doing independent research projects, and by members of the spring 1994 and 1995 undergraduate course in ecology at Cleveland State University. Training of the tape processors included field trips with faculty and/or experienced graduate students to identify calls and listening to recorded calls of known species (e.g., "The Calls of Frogs and Toads: Eastern and Central North America," Lang Elliott NatureSound Studio, Ithaca, New York, 1992). Competence of the tape processors was tested by scoring their ability to recognize species from previously processed tapes. For most cases, two or more people processed a single tape, and an experienced graduate student spot-checked the results. If processors noted ambiguous or unidentified calls, these were checked by experienced graduate students and faculty (e.g., B.M.W. and A.R.G.). All tapes were retained for future reference and verification.

We sought to determine diversity, distribution, and seasonal calling schedules of anurans in the CVNRA. Two sampling methods were used to accomplish these goals simultaneously. To determine diversity and distribution of anurans in the CVNRA, one automated recorder was moved among ten different sites (Fig. 18-1; Table 18-1), returning to the same location approximately every ten days. The second recorder remained at a single location (Prucek Pond, Fig. 18-1; Table 18-1) throughout the breeding season to collect more detailed data on species richness and seasonal variation in calling activity.

Salamander Survey

We surveyed twelve sites within the CVNRA (Fig. 18-1; Table 18-2) that were chosen to sample as many habitat types as possible and to include ten that have been surveyed previously by others (Mazzer et al. 1984; Walker 1946). Surveys were conducted from April through August. Each site was surveyed an average of seven times (minimum = one, maximum = twenty-three).

Surveys were conducted by searching 2-by-25-meter transects. Two observers searched the surface of the transect thoroughly by raking leaves and debris and overturning all rocks and logs. All cover objects were replaced. The general information recorded at the time of each survey included date, beginning and ending time, location, major topographic and vegetative features, weather conditions (e.g., clear, overcast, windy, rain), air, and, if appropriate, water temperature (using an Omega HH23 electronic thermocouple thermometer). We attempted to capture all salamanders within each transect. Data for each animal captured included species, sex, snout-vent length (SVL), distinctive color and pattern characteristics, and other information pertaining to the health and condition of the animal (e.g., gravid, broken tail). All animals were released at the point of capture within one hour of collection.

Results

Performance Evaluation of the Automated Recording Device

Acoustic Performance. Call reception by the automated recording device was as good as that of a trained, experienced listener stationed the same distance from the sound source. The least-squares regression line relating call reception by the recorder to call reception by the observer (the solid diagonal line in Fig. 18-2; $r^2 = 0.77$, $n = 35$) was not significantly different from a hypothetical line of equal performance (the dashed diagonal line in Fig. 18-2; slope of 1, Y-intercept of 0). The slope of the regression line was significantly greater than 0 (0.90 ± 0.08 standard error; $t = 10.79$, $p < 0.001$) but not significantly different from 1 ($t = -1.35$, $p > 0.20$), and the Y-intercept (0.11 ± 0.18 standard error) was not significantly different than 0 ($t = 0.578$, $p > 0.50$).

As is to be expected, quality of the recordings decreased as the distance between the sound source and recorder increased (Figs. 18-3, 18-4; Table 18-3). Recording quality also varied with direction (Figs. 18-3, 18-4; Table 18-3), largely due to variation in topography and vegetation (Fig. 18-3). Calls produced 50 meters away from the device generally were highly audible upon playback when there were no obstructions between the recording device and the sound source (Figs. 18-3, 18-4). In the case of Prucek Pond, recordings of

Table 18-2. Salamander survey sites at the CVNRA, brief descriptions of each site, and the species found during three separate surveys. Site identification numbers appear in parentheses following the site names (see Fig. 1). Abbreviations: Df-*Desmognathus fuscus*; Eb-*Eurycea bislineata*; El-*Eurycea longicauda*; Nv-*Notophthalmus viridescens viridescens*; Pc-*Plethodon cinereus*; Pg-*Plethodon glutinosus*; Pr-*Pseudotriton ruber*.

		Species Found		
Location	Description	Mazzer et al. 1984	Varhegyi et al. 1995	Varhegyi et al., this chapter
Brecksville (1)	Rocky creeks in secondary hickory-maple forest	*	Df, Eb, Pc, Pg	Eb, Df, Nv, Pc
Brandywine Road (2)	Secondary growth forest including sycamore and pine trees, well-shaded ravines	Eb, Nv, Pg	Df, Eb, Pc	Df
Columbia Run (3)	Sandy bottom creek in well-shaded ravines	Eb	*	Df
Blue Hen Falls (4)	Flat shale stone bottom creek at bottom of several hills with secondary growth, including oak and beech trees	Eb, Nv, Pc, Pg	Pc	Df, Eb, Pc
Ledgewood Camp (5)	Well-shaded ravine along hiking/biking trail in secondary growth forest	Df, Eb, El, Pc, Pg, Pr	Df, Eb, Pc, Pg, Pr	Df, Eb, Pc
Deep Lock Quarry (6)	Secondary growth sycamore and oak trees forest, adjacent to farmland	Eb, Pc, Pg	Eb	*
Octagon (7)	Many well-shaded ravines in secondary hickory-maple forest with many sandy and rocky creeks and seeps	Df, Eb, Pc, Pr	Df, Pc, Eb	Df, Eb, Pc
Kendall Lake Area (8)	Large lake (ca. 5 acres), fed by stream, surrounded by secondary growth forest	Eb, Pc, Nv	Df, Eb, Pc	Df, Eb, Pc, Pr
Oak Hill Road (9)	Near road with relatively flat topography, plants include beech, pine, tulip, and sycamore trees	Df, Eb, Pc, Pg	*	Df, Eb, Pc
Valley Picnic Area (10)	Secondary growth with steep ravines, shale stone creeks that often dry in late summer	*	Eb, Pc	Eb, Pc
Furnace Run (11)	Low sloping ravines adjacent to farmland	Df, Eb, Pg	Df, Eb, Pc	Df, Eb, Nv, Pc
Indigo Lake Area (12)	Flat topography with secondary forest adjacent to a major road	Eb	*	Eb, Pc

*Site not surveyed.

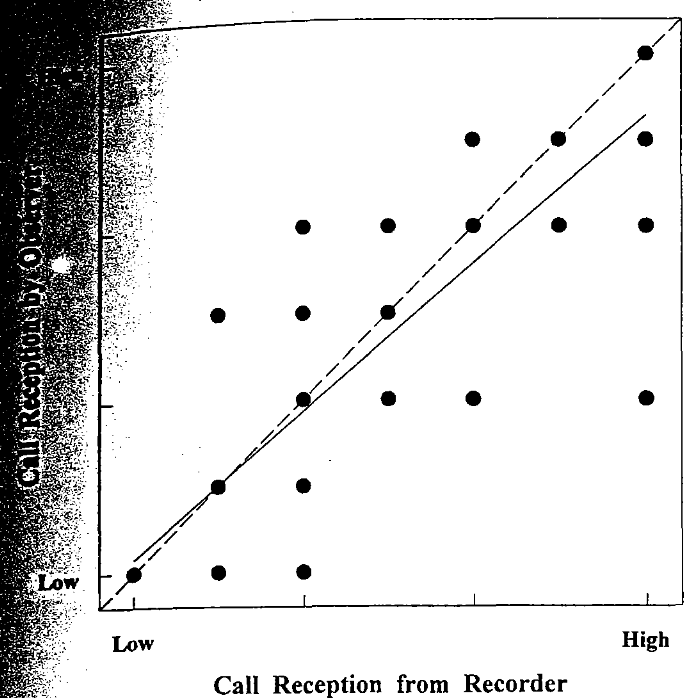

Figure 18-2. Call reception by observer plotted against the call reception from the automated recorder. "Low" indicates no sound reception. The dashed line represents a one-to-one ratio. The solid line is the least-squares regression line through the data points.

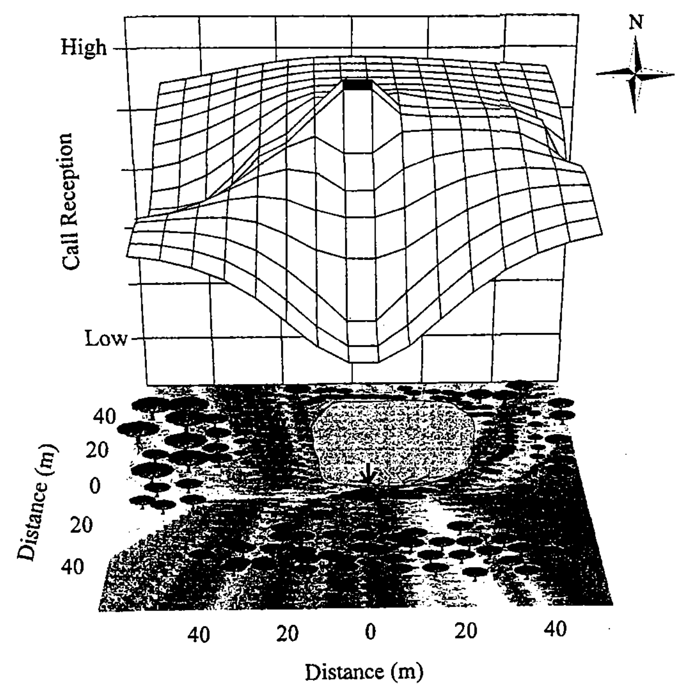

Figure 18-3. Sound reception, assessed subjectively from the automated call recorder, of calls of spring peepers played at a standard intensity at various locations around Prucek Pond (Site F11, Fig. 18-1). The location of the automated recorder (coordinates 0,0) is indicated by the arrow; sound reception of calls played immediately beside the recorder is marked by a rectangle. The plotted three-dimensional mesh surface was fitted using inverse distance weighting (Jandel Scientific).

high quality were obtainable from the entire pond area and from a band approximately 10 to 20 meters away from the pond margins in all directions. This area encompassed the principal calling sites of all species found at Prucek Pond (Table 18-1). Calls were attenuated most severely by dense vegetation, forests, and hillsides to the south and west of the pond (Figs. 18-3, 18-4).

The quality of recordings also differed with the species producing the call, independent of direction or distance (Fig. 18-4; Table 18-3). Recordings of spring peepers were of higher quality generally than were those of the other species tested, regardless of direction or distance (Fig. 18-4). Calls of western chorus frogs attenuated most rapidly with distance (Fig. 18-4).

Population Density Estimates. Population density estimates based on recordings from the automated device were underestimates, but strongly predictive, of the actual number of male gray treefrogs calling at Prucek Pond in 1994. Figure 18-5 illustrates estimated and actual counts of the number of male eastern gray treefrogs calling each night at Prucek Pond for a thirty-one-day period in the summer of 1994 (simultaneous counts and estimates are available for twenty-five of thirty-one days). Direct observational censuses found, on average, 0.48 (± 0.44 standard error) males calling each night. Population estimates obtained with the automated recording device indicated that 2.8 (± 0.26 standard error) males were calling each night. The estimates based on the automated recorder underestimate the actual counts by 38 percent on average. This differential was not constant, however (Fig. 18-5). The slope of the least-squares regression relating estimates to direct counts has a Y-intercept not significantly different than 0 (0.543 ± 0.325 standard error, $t_{Y\text{-int}=0} = 1.67$, $p > 0.10$) and a slope that was significantly greater than 0 (0.503 ± 0.0655 standard error, $t_\beta = -7.68$, $p < 0.001$) but less than 1 ($t_\beta = -7.59$, $p < 0.001$). Hence, the amount by which the automated device underestimated the number of calling males increased as the actual number of calling males increased. Neverthe-

Table 18-3. Analysis of covariance testing for the effects of species (*Bufo americanus americanus, Hyla versicolor, Pseudacris crucifer crucifer,* and *Pseudacris triseriata triseriata*), compass direction (N, S, E, W), and distance from the sound source (10, 20, 30, 40, or 50 m) on quality of recordings obtained by the automatic call recorder

Source of Variation	Degrees of Freedom	Mean Square	*F*-statistic	*P*
Species	3	2.947	15.461	<0.001
Direction	3	7.275	38.167	<0.001
Species x Direction	9	0.086	0.454	0.900
Distance	1	2.219	11.643	0.001
Distance x Species*	1	0.038	0.198	0.658
Distance x Direction†	1	0.633	3.320	0.073
Error	61		0.191	

*Tests for homogeneity of slopes for the relationship between distance and audibility of recordings among species.
†Tests for homogeneity of slopes for the relationship between distance and audibility of recordings among directions.

less, estimates based on the recorder were strongly predictive of the number of calling males actually counted. Night-to-night variation in the direct counts was reflected in variation in the estimates (Fig. 18-5).

Anuran Survey

1994 and 1995 Surveys. Nine species of anurans were identified in the CVNRA through two years of call surveys, comprising over 138 hours of recordings. Total number of species recorded, or species richness, did not differ among the two years of the survey (two-way analysis of variance, $F_{1,10} = 0.204$, $p = 0.661$), although this and subsequent tests that lack replication may only be sensitive to large effects. Sites, however, differed in species richness (two-way analysis of variance, $F_{10,10} = 3.054$, $p = 0.046$). Also, variation in species richness among sites in 1994 was not correlated with species richness in 1995 ($r_P = 0.51$, $n = 11$, $p = 0.11$); the number of species found at a particular site in 1994 was not predictive of the number of species found in 1995. Species richness per site, averaged over both years, was 4.8 species/site (standard error = 0.4, range = 2 to 8 species/site).

Our data are not sufficient yet to establish statistical trends of abundance for individual species. However, these data clearly indicate site-by-site (Fig. 18-6) and yearly variation (Figs. 18-7, 18-8) in the numbers of calling anurans. Year-to-year variation in intensity and duration of calling activity was especially evident at the continuously monitored site, Prucek Pond. We obtained 41.3 hours of recordings in 1994 and 30.2 hours of recordings in 1995 at Prucek Pond (sampling eighty-six and sixty-four days, respectively). The number of calls produced per night and the length of the breeding season were reduced in 1995 in comparison to 1994 (Figs. 18-7, 18-8). All species were affected, but several are particularly noteworthy. Eastern gray treefrogs, for example, were active almost every night from June through early July in 1994 but called only a few nights and in small numbers during the same period in 1995. Similarly, green frogs (*Rana clamitans melanota*] were abundant and active throughout the summer of 1994 but were active at similarly high levels only on a few nights toward the latter part of the season in 1995. Pickerel frogs (*Rana palustris*) were seldom heard in the spring of 1994 and were even less common in 1995.

Comparison to the 1983 Survey. Species richness differed significantly between the study of Mazzer et al. (1984) and the current survey at the same sites in the Cuyahoga Valley (one-way analysis of variance, $F_{2,27} = 3.81$, $p = 0.035$). The average species richness reported in Mazzer et al. (1984) of 2.6 species per site (standard error = 0.53, range = 1–5 species/site) was only about 55 percent of the 1994 (4.9 species per site) and 1995 (4.6 species per site) averages, a significant difference

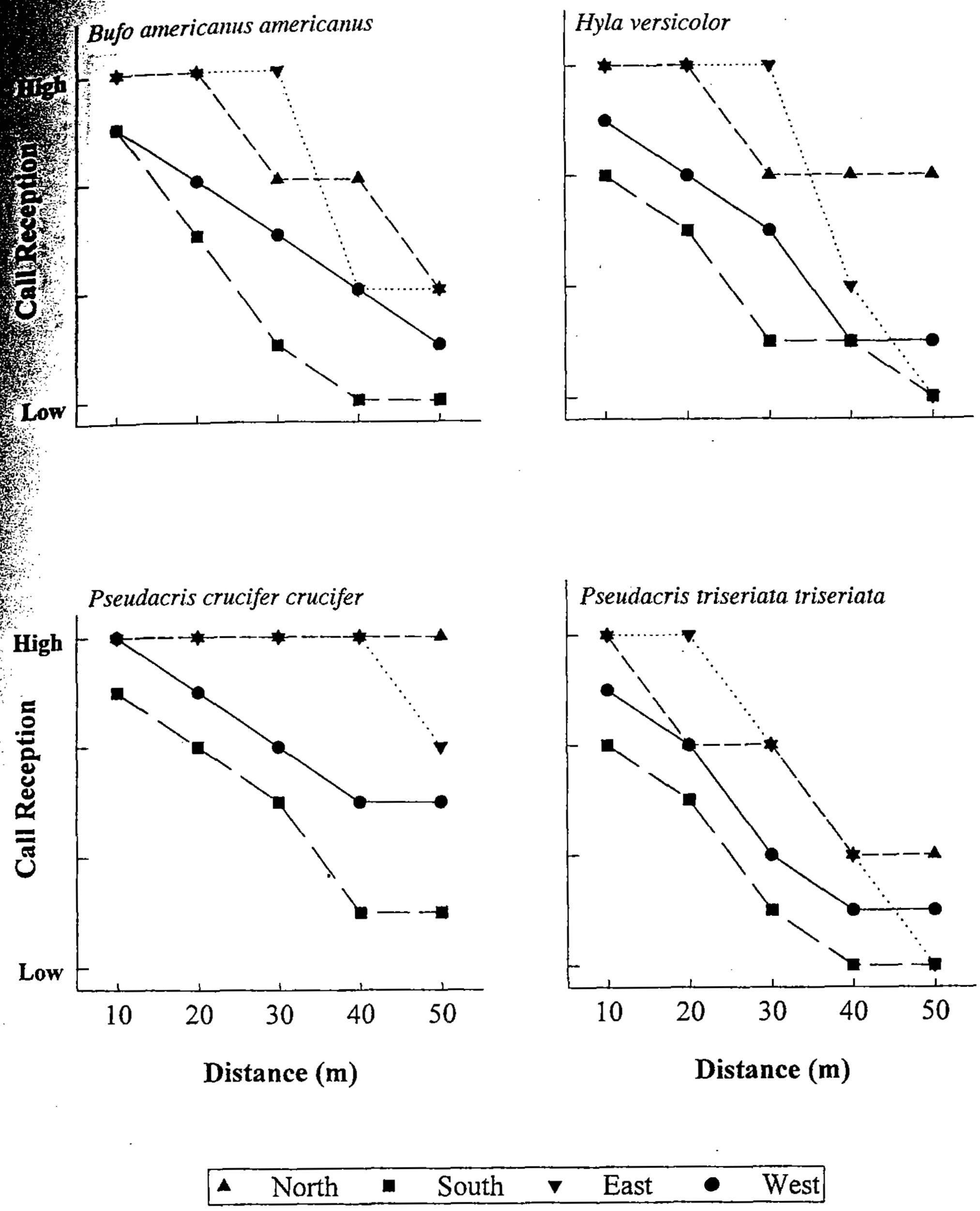

Figure 18-4. Sound reception, assessed subjectively from the automated call recorder, of calls of American toads, gray treefrogs, spring peepers, and chorus frogs played at a standard intensity at various locations and distances around Prucek Pond (F11, Fig. 18-1).

(Student-Newman-Keuls a posteriori multiple range test, $p < 0.05$). Furthermore, variation in species richness among sites in 1983 was not predictive of species richness in 1994 (Spearman rank correlation, $r_s = 0.01$, $n = 8$, $p = 0.99$) or 1995 ($r_s = 0.44$, $n = 8$, $p = 0.28$).

We found all the species reported by Mazzer et al. (1984) and one species, northern leopard frogs (*Rana pipiens*), not found by those workers. Northern leopard frogs were recorded at one site (F3, Snowville) on one evening in 1994. Mazzer et al. (1984) reports only presence/absence of species, data which are not sufficient for more detailed comparisons of species composition and abundance among sites.

Salamander Survey

1994 and 1995 Surveys. Six species of terrestrial and

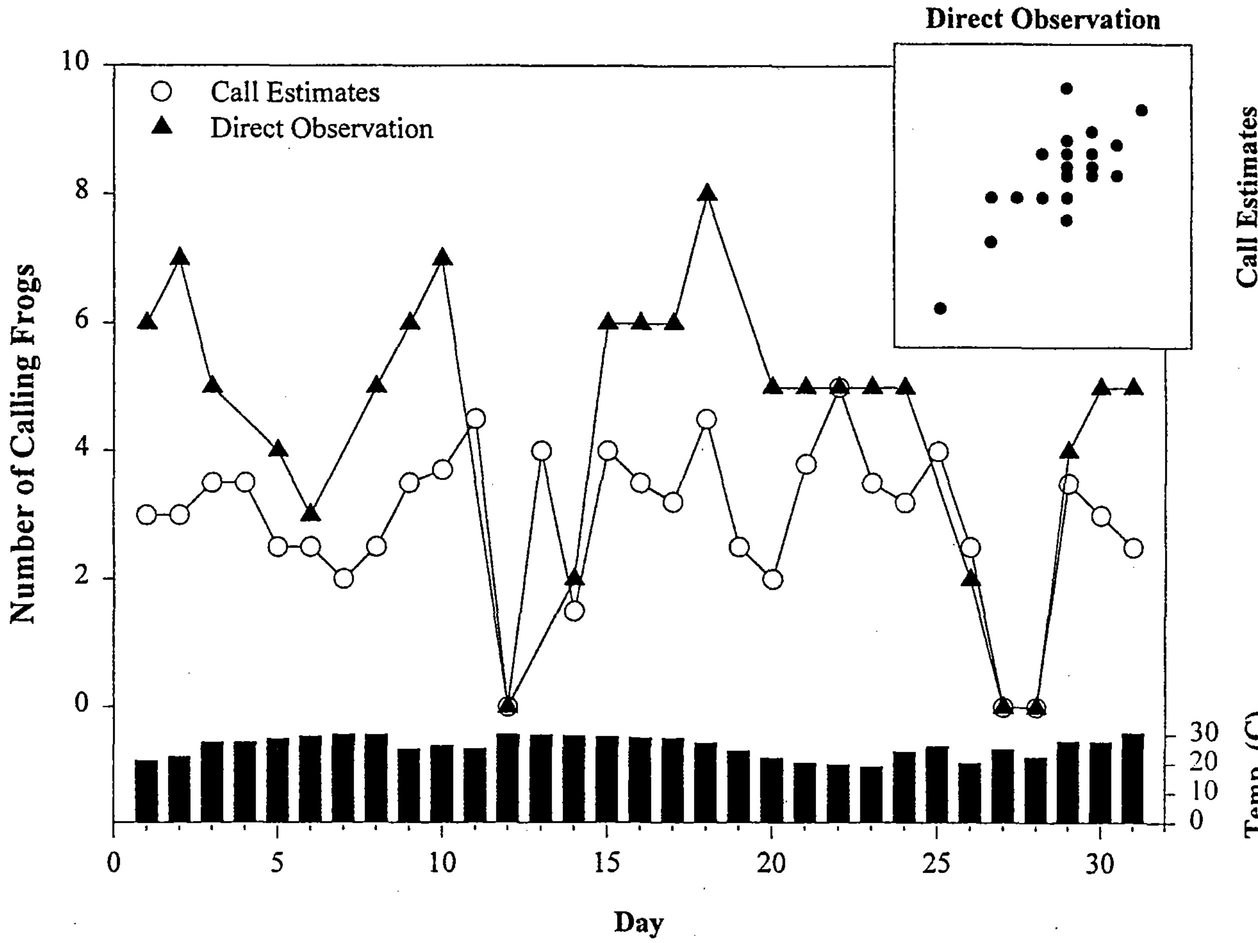

Figure 18-5. The number of calling male eastern gray treefrogs (*Hyla versicolor*) and daily average water temperatures at Prucek Pond plotted across the 1994 breeding season. Triangles are counts of calling males based on direct observation; circles are estimates of the number of calling males based on the automated call recorder (see text). The histogram represents daily average water temperature, and the insert is estimated call totals plotted against the direct counts of calling males.

stream-side salamanders were found in the CVNRA in over 200 person-hours of observation. Species richness did not differ among years (two-way analysis of variance, $F_{1,7} = 0.001$, $p = 1$) or among sites ($F_{11,7} = 1.703$, $p = 0.246$). Species richness at a site in 1994 was not predictive of species richness at that site in 1995 ($r_s = 0.33$, $n = 8$, $p = 0.33$). Mean species richness for 1994 and 1995 combined was 2.8 species/site (standard error = 1.16, range = 1 to 5).

Of the 1,546 individual salamanders found, three species accounted for 99.2 percent of captures: northern dusky salamanders (*Desmognathus fuscus*; 38.2 percent), northern two-lined salamanders (*Eurycea bislineata*; 31.8 percent), and redback salamanders (*Plethodon cinereus*; 29.2 percent). The abundance of these three species varied among sites (Fig. 18-9; chi-square test of association, $\chi^2 = 561.64$, $p < 0.0001$). These species also showed monthly trends of abundance (Fig. 18-10). Northern two-lined salamanders and redback salamanders were most abundant in spring and decreased in our captures in summer. Northern dusky salamanders, in contrast, were scarce in spring and early summer but abundant in late summer.

Comparison to the 1983 Survey. Species richness of terrestrial and stream-side salamanders did not differ between the current and 1983 (Mazzer et al. 1984) surveys (one-way analysis of variance, $F_{2,27} = 0.406$, $p = 0.671$). Species richness in 1983 was not predictive of species richness in 1994 ($r_s = 0.33$, $n = 7$, $p = 0.47$) or 1995 ($r_s =$

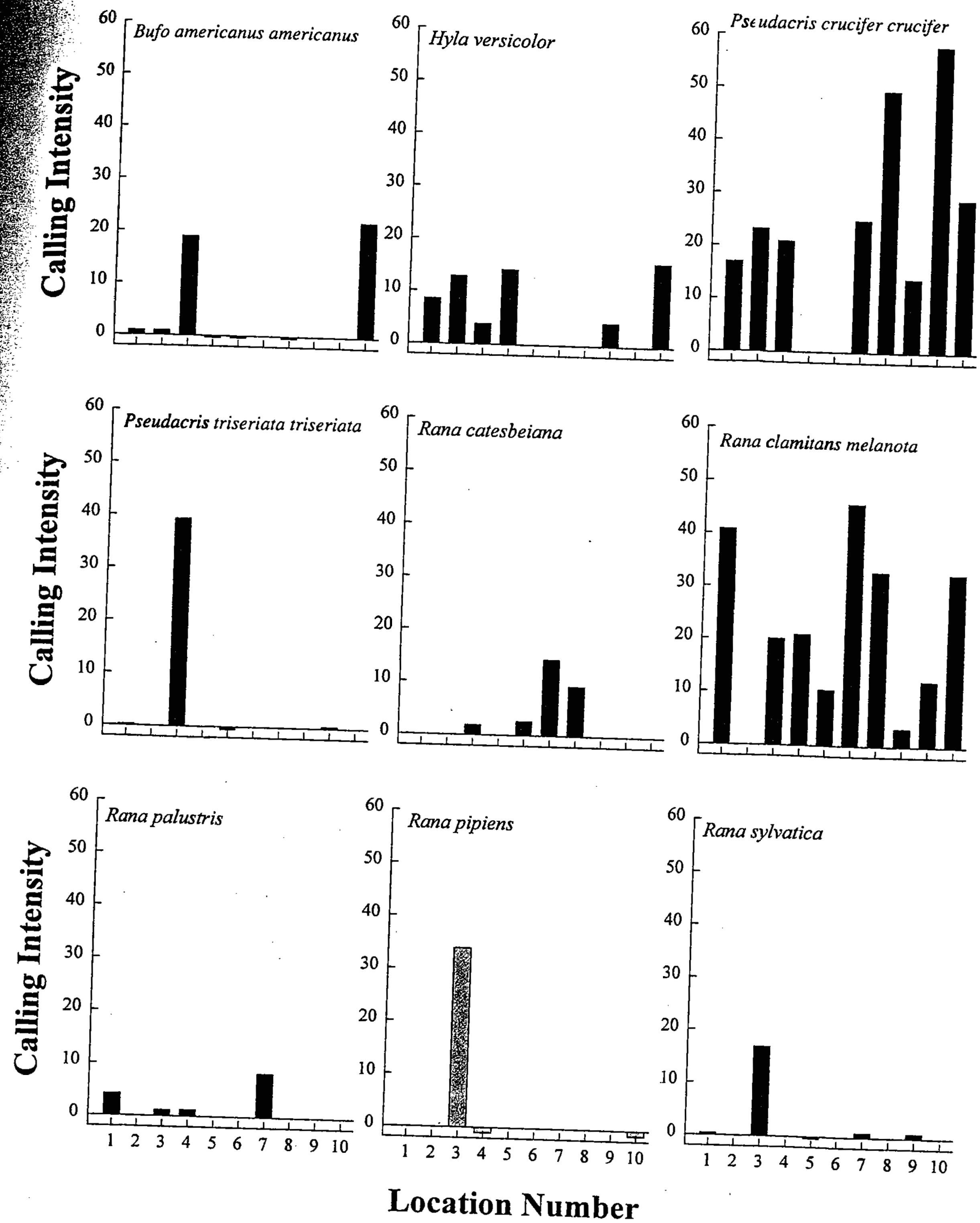

Figure 18-6. An index of calling intensity at each of the periodically surveyed locations in 1994 (Fig. 18-1; Table 18-2) plotted separately for the nine species of anurans recorded from the CVNRA. The calling index is the daily average number of sampling intervals that recorded calls. For each species, calculations were based only on intervals that fell within that species' breeding season. Negative values represent sites not visited during that species' breeding season as defined by the earliest and latest dates of calling. For northern leopard frogs (*Rana pipiens*) which we recorded only on one day, we have assumed a two-week breeding season.

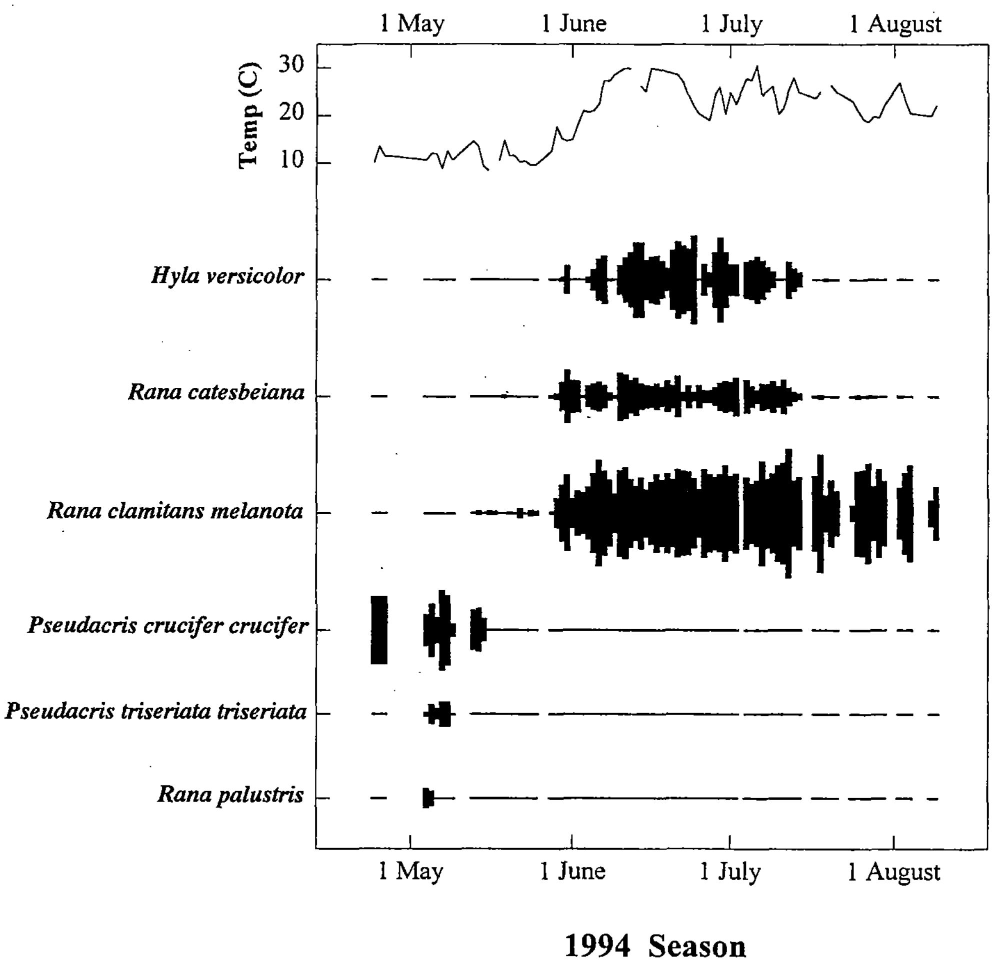

Figure 18-7. Calling activity of six species of anurans and average daily temperature plotted across the 1994 breeding season. The vertical range of each solid bar about the horizontal midline represents the total number of sampling intervals with calls in a twenty-four-hour period.

0.38, n = 9, p = 0.314). Mazzer et al. (1984) found 3.2 (± 0.47 standard error) species per site (range = 1 to 6) in 1983.

We found six of the seven species found in 1983 (Mazzer et al. 1984) but were unable to relocate longtail salamanders (*Eurycea longicauda*), despite repeated searches in 1994 and 1995 of their locality (S5, Ledgewood Camp, Fig. 18-1; Table 18-2).

Discussion

Performance of the Automated Call Recorder

The automated call recorder, often termed a "froglogger," designed by Peterson and Dorcas (1992, 1994) is an effective tool for monitoring calling anurans. The device has many attractive features: (1) an ability to obtain continuous, long-term records of calling activity without relying on human observers; (2) sensitivity of the device to rare species (because of the long records); (3) little or no disturbance of calling anurans, thereby increasing the likelihood of detecting easily disturbed species; (4) sampling of several sites simultaneously (with multiple recorders); (5) ability to correlate environmental conditions with calling activity (if the device is equipped with environmental monitoring devices); and (6) a permanent record that can be used to investigate long-term trends and to verify species identifications (Corn et al. 1995; Dorcas et al. 1995; Varhegyi et al. 1995).

The froglogger, however, is relatively new and has

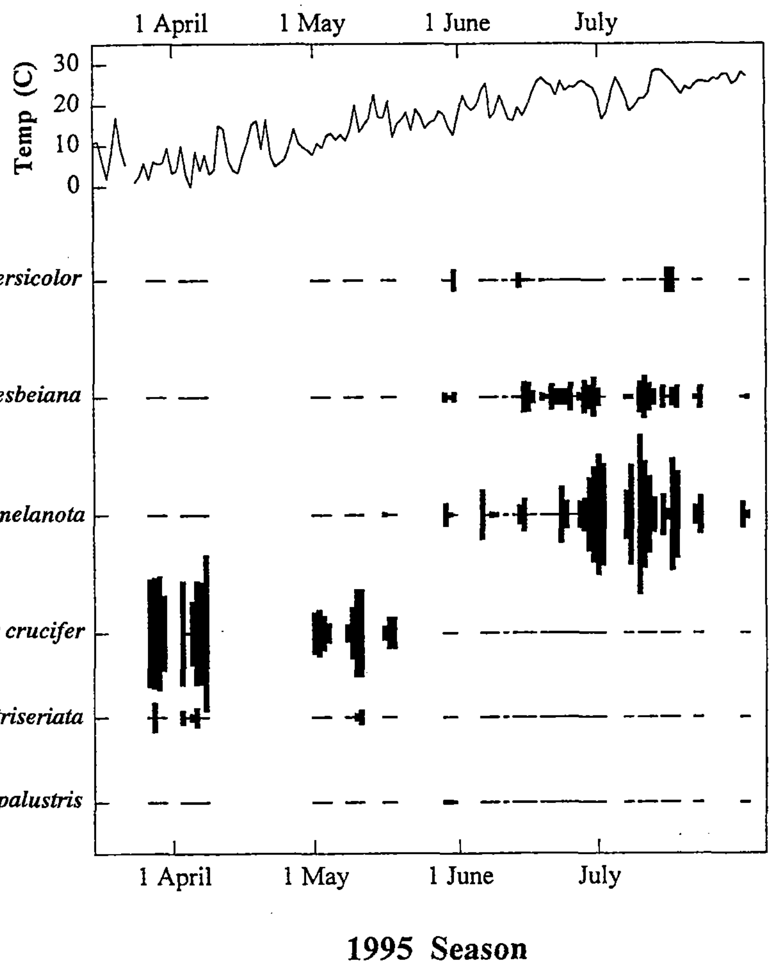

Figure 18-8. Calling activity of six species of anurans and average daily temperature plotted across the 1995 breeding season. The vertical range of each solid bar about the horizontal midline represents the total number of sampling intervals with calls in a twenty-four-hour period.

been used to monitor only a few species in a few habitat types (e.g., Berrill et al. 1992; Dorcas et al. 1994). Before it can be applied generally to anuran population monitoring, it must perform well relative to several criteria. First, it should provide an accurate record of species present at a locality. This means it should sample all species well, regardless of acoustic properties of their calls or length of calling activity (e.g., explosive versus prolonged breeders). Second, it should perform well in all habitats. Third, it should provide data for accurate estimates of population sizes. Finally, it should be cost effective (i.e., low cost per datum). No technique may be expected to satisfy all of these criteria completely. However, the froglogger must perform well according to these criteria in comparison to traditional methods (e.g., roadside surveys and aural transects) if it is to receive broad acceptance. Our goal was to evaluate the device against these criteria.

Overall, the ability of the automated device to record audible calls was as good as the ability of trained, experienced humans to hear those calls, at least within 50 meters of the sound source (Figs. 18-3, 18-4). Previous workers, however, have noted that the froglogger may not obtain audible recordings of all species or individuals present in some habitats (Berrill et al. 1992; Dorcas et al. 1994). Our experiments indicate that variation in acoustic performance with distance, vegetation, and species (Figs. 18-3, 18-4; Table 18-3) may contribute to such underestimates.

Our experiments provide lessons for effective place-

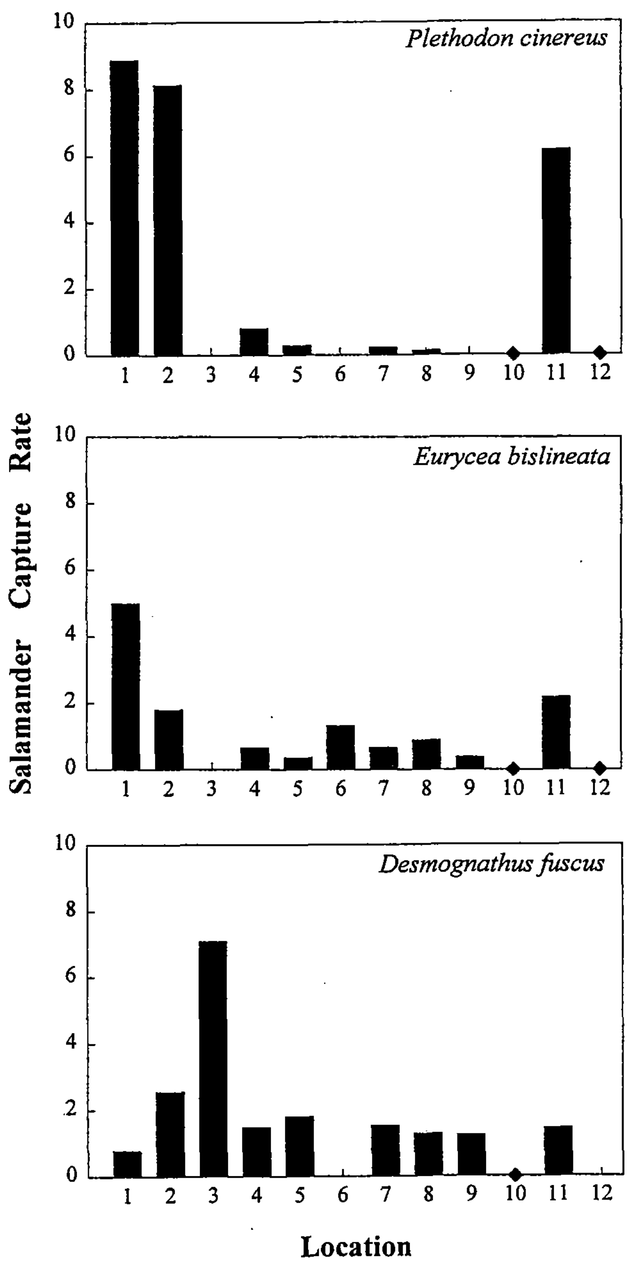

Figure 18-9. An index of salamander abundance at each of the periodically surveyed locations (Fig. 18-1; Table 18-2) plotted separately for the three most abundant species in the CVNRA. The index is the number of salamanders captured per person-hour of search time, combining data for 1994 and 1995. Diamonds represent sites where a species occurred but where data were insufficient for a meaningful index to be calculated. Sites with no bar or diamond represent no capture.

ment of the froglogger. Calls attenuate with distance, and the rate of attenuation varies with the species producing the call (Fig. 18-4; Table 18-3) and with the degree of obstruction by vegetation or topography (Fig. 18-3). As expected, the device functions best when the sound field is free of obstruction. This criterion often is met for species that call from the pond edge or the water but may not be for species that call from under, on, or within vegetation. Further, open areas may be uncommon in wetlands containing dense emergent vegetation (e.g., grassy marshes, bayous). Nevertheless, we obtained audible recordings through 20 meters or more of substantial vegetation (Figs. 18-3, 18-4).

Given these considerations, it may be prudent for investigators using the froglogger to map the sound field of their site in a fashion similar to that depicted in Figure 18-3 and to test the sensitivity of their device to calls of species likely to occur, as shown in Figure 18-4. Although this may take some time, it should reveal the most effective location for placement of the device.

Intensive, continuous monitoring of population sizes (of calling males, at least) and the correlation of population size with environmental parameters promise to be among the most useful applications of the froglogger. In our view, the ability to monitor several sites simultaneously provides an excellent tool for investigating regional variation in population cycles. Population monitoring with this device certainly is much less disruptive and labor intensive than it is with mark-recapture methods.

Although the automated device underestimated the number of calling male gray treefrogs at Prucek Pond by 38 percent on average, population estimates based on the froglogger were strongly correlated with direct counts. We consider this a promising result, indicating that the device is useful for monitoring population size. However, the investigator first must establish the relationship (e.g., through regression analysis) between counts and froglogger-based estimates. Methods for minimizing the discrepancy between counts and froglogger estimates will be helpful.

Difficulty in distinguishing overlapping calls from two or more individuals is the most likely cause for the discrepancy between counts and estimates. Discrimination became especially problematic when population densities were high, as reflected in the increasing differential between estimates and counts as population size increased (Fig. 18-5). Berrill et al. (1992) reported similar difficulties when using the device for monitoring of anuran populations in southern Ontario. However, human

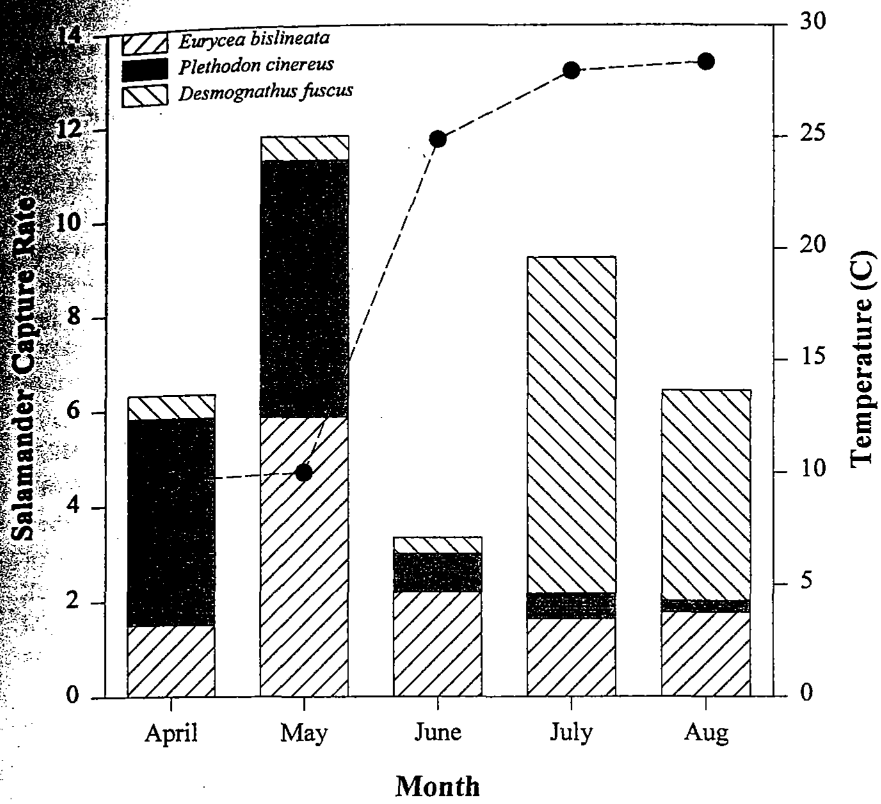

Figure 18-10. Monthly capture rates, an index of abundance, for three species of salamanders and average temperatures. The histogram represents the index, which is the number of salamanders captured per person-hour of search in the CVNRA during 1994 and 1995. Circles represent average monthly temperatures for both years.

listeners stationed at breeding choruses also have difficulty discriminating overlapping calls (Berrill et al. 1992). Because the froglogger tape is a permanent electronic record, it provides some options to minimize this problem that are not available in listener-based techniques. For example, when such conflicts arose in our data, they were addressed by replaying the calls to several trained listeners to obtain independent call counts and/or by inspection of a sonograph of the recording (this was necessary for particularly problematic overlaps of greater than three individuals). In this way, we were able to distinguish individual calls on most recordings. These procedures can be time-consuming, however. Perhaps digital recording systems and pattern recognition software currently in development (Patrick et al. 1995) will address this problem more efficiently.

Temperature variability in calling rates may also have contributed to the discrepancy. Call rates of eastern gray treefrogs generally increase with temperature (Bogart and Jaslow 1979; Gayou 1984), but the call rate used to estimate population size was the average for this population. This may not have been a major difficulty in 1994, because temperatures showed relatively little variation during the eastern gray treefrog breeding season. Nevertheless, we will incorporate temperature-dependence into our estimation algorithm in the future.

Cost is a major factor determining the utility of a monitoring technique. Considering that funding levels for biodiversity work are low and are likely to remain so, no monitoring technique will be accepted widely if it is too expensive, no matter how effective. Unquantified concern that the froglogger is prohibitively expensive for most applications has found its way into the draft "Protocols and Strategies for Monitoring North American Amphibians" (North American Amphibian Monitoring Program 1996; Mac 1996).

Our experience, however, is that the froglogger is much less expensive than is a traditional drive-by survey and indeed is highly cost-effective. We can construct a froglogger for under $300 (less than $200 if we do not equip the devices with temperature data loggers). Costs for gasoline, recording tapes, and replacement parts have averaged less than $250 per year. These costs compare favorably with those for surveys conducted by more traditional methods. For example, the Ontario Task Force on Declining Amphibian Populations has instituted a program of amphibian road call counts (Gartshore et al. 1995). Volunteer participants in this survey drive 7.2-kilometer routes and listen for three minutes each at ten survey points along the route. Each volunteer repeats this route three times during the season for a total of ninety minutes of survey time. In the CVNRA in 1994 and 1995, we surveyed for 8,320 minutes using the automated recorder. A volunteer listener-based survey of the same duration would require ninety-two volunteers, and the cost would be approximately 3.2 times that of the froglogger survey (Table 18-4). Moreover, the froglogger generates permanent audio records that provide easier verification and greater detail than do the corresponding data from drive-by surveys. Corn et al. (1995) conducted a similar cost comparison and found that volunteer-based surveys may cost up to ten times as much as froglogger surveys, per datum.

Drive-by, listener-based surveys in general may yield data that are more expensive, less cost-effective, and less useful than are data from surveys based on automated call recorders. With automated call recorders, the contributions of experienced, motivated volunteers simply may shift from direct data acquisition to servicing the call recorder and processing the data tapes. Frogloggers need to have their batteries recharged and tapes replaced on a routine basis, and in some studies the froglogger itself may need to be rotated around survey sites. Froglogger tapes need to be played back, the recorded calls must be identified accurately, and the data obtained must be transcribed reliably. Obviously, but crucially, all these tasks are best performed by experienced workers who believe in the importance of this program.

Anuran Surveys

Two years is not enough time to establish trends in population change in the amphibians of the CVNRA. The current surveys, however, do establish a basis for subsequent monitoring and provide some useful, albeit preliminary, comparisons to previous surveys.

Perhaps the most remarkable finding was that overall anuran species richness has apparently not changed over at least the past ten years. Our results, in fact, indicate a statistically significant 45 percent average increase in the number of species per site in comparison to 1983. However, we suspect that this increase is attributable more to the intensive sampling made possible by the froglogger than to an actual increase in species numbers. Nevertheless, we were impressed that we found no significant decrease in species richness, despite many human impacts on the CVNRA and the extensive urbanization of surrounding areas. This may be a testament either to the value of habitat protection and sound resource management to amphibian conservation, even in heavily urbanized areas, or to the low power of the

Table 18-4. Approximate cost comparison of two anuran survey methods, based on surveying 8,320 minutes

	Froglogger	Listener-Based Survey
Start-up cost	$200/froglogger x 2 = $400	92 kits[1] x $14/kit[2] = $1288[3]
Topographic map	2 x $9[4] = $18	92 x $9 = $828
Fuel	289 days x $0.45 per day[5] = $130	92 ind. x $0.45/visit x 3 visits = $124
Cassette tapes	289 days x 1 tape/2 days x $1/tape = $145	
Total	$693	$2,240

[1] Survey kits contain instructions, data sheets, training tapes, vehicle signs, etc.
[2] Amy Chabot (personal communication).
[3] These costs will be greater if not all participants return properly completed survey forms. Typical survey response rates may be less than 10 percent (Mahar et al. 1995).
[4] Gartshore et al. 1995.
[5] Value based on $0.10 per mile and a 4.5-mile route.

ests. The CVNRA, however, was established only in 1974. Therefore, the area already was heavily affected prior to implementation of habitat protection. The most serious declines may have occurred during this earlier period. As best as we can tell, this was the time when the once-abundant northern leopard frog underwent its most rapid decreases (discussed below).

We located all nine species of anurans reported to be present historically in or near the CVNRA by Walker (1946). Orr (1978) and Mazzer et al. (1984) provide more recent lists of species within the CVNRA; they located eight of the nine species reported by Walker (1946). The one species lacking from the Orr (1978) and Mazzer et al. (1984) lists was the northern leopard frog, a species in general decline throughout much of its former range (Stebbins and Cohen 1995). Other records indicate that this species was present in the 1970s (MacLaren 1959; Jack McCormick and Associates 1975) in the area that is now the CVNRA, although Mazzer et al. (1984) suspect that these records were misidentified pickerel frogs. Nevertheless, northern leopard frogs were abundant in northeastern Ohio through the mid-1950s (Dexter 1955). We recorded a single northern leopard frog on 18 April 1994 at Snowville Pond. Hence, the species either has persisted essentially undetected for at least twenty years or has reinvaded the area from surrounding areas. Given the extensive development of areas surrounding the CVNRA, we consider the latter possibility unlikely. This recording also attests to the effectiveness of the froglogger for finding rare species.

It is difficult to distinguish trends in other anurans from the available data, but two species merit mention. Bullfrogs (*Rana catesbeiana*) were considered "well established" by Mazzer et al. (1984) but were not found by them in large numbers at any locality in the CVNRA. Our survey, which also found that population sizes at any particular locality are not large, nevertheless documented that bullfrogs have invaded areas in which they were not found in the 1980s (e.g., Valley Picnic Area, F6, Indigo F10), expanding their range to include more southerly areas of the CVNRA. Mazzer et al. (1984) considered wood frogs (*Rana sylvatica*) to be common, even though they located this species only near Kendall Lake. We found wood frogs at sites throughout the CVNRA in 1994, although not at Kendall Lake, but we did not find them at any sites in 1995. We can identify no obvious factor causing the difference for this species between 1994 and 1995. Perhaps this merely reflects the natural potential for dramatic population cycles often characteristic of amphibian species (e.g., Pechmann et al. 1991).

Salamander Surveys

Any statements concerning trends in population sizes or species diversity of salamanders must be considered preliminary. However, the stability of anuran species richness between 1983 and the current survey is mirrored in the terrestrial and stream-side salamanders, suggesting again that habitat protection since 1974 has been beneficial to the amphibians of the CVNRA.

Despite the overall consistency of species richness, our survey indicates possible declines among some salamander species within the CVNRA. Longtail salamanders, for example, have been reported at one location in the CVNRA (Ledgewood Camp, S5) as recently as 1983 (Mazzer et al. 1984; Pfingsten and Downs 1989). However, we were unable to find a single individual, despite repeated visits to this locality over two years, and Sipes (1964) described it as "uncommon" in northeastern Ohio. Similarly, although northern slimy salamanders (*Plethodon glutinosus*) have been considered to be "relatively common" in the park (Mazzer et al. 1984) and "very common" in northeastern Ohio (Sipes 1964), we found a total of six individuals from only two sites in 1994 (fewer than in 1983) and no individuals in 1995. We consider this species now to be uncommon in the CVNRA. Ravine salamanders (*Plethodon richmondi*) are known from the area now occupied by the CVNRA from only a single specimen collected by Walker (1931; Ohio State University Museum 1438). We found none, despite repeated sampling of suitable habitat, the wooded slopes of valleys and ravines (Pfingsten and Downs 1989). Similarly, we found no four-toed salamanders (*Hemidactylium scutatum*), known previously from a single location in the CVNRA (Brecksville, S1; Orr 1978).

Conclusions

Some natural areas in what now is the CVNRA already were protected by state agencies, local parks, and private organizations prior to the establishment of the park (Cockrell 1992). However, the establishment of the CVNRA in 1974 brought greater protection to the area's amphibians and to their habitat. Yet by that time, extensive industrial and residential development had encroached upon the area, bringing multiple threats to amphibians and other natural resources of the CVNRA: acid rain; recycling plants; dumps; landfills; junkyards;

oil and gas drilling; commercial removal of topsoil, limestone, clay, sand, and gravel; pesticides; toxic wastes; illegal or accidental dumping of chemicals and biological wastes into the Cuyahoga River and its tributaries; salt runoff from roads; silting of streams; stream bank destruction; roads and traffic that disrupted migratory movements; introduced exotic species; marijuana cultivation; and numerous other possible threats "constrained only by an individual's imagination" (Cockrell 1992). The NPS and local agencies have taken great strides in mitigating many of these impacts, particularly in the area of water quality. Many of the streams in the park now meet or exceed federal water quality standards (Cockrell 1992). However, many problems still remain from threats both inside and outside the park.

One would hope that the efforts of the NPS and others have resulted in stabilizing local amphibian populations. Unfortunately, there are few data with which to assess this hypothesis. The only reliable data have been collected after the implementation of NPS management (e.g., Mazzer et al. 1984). Comparison of our results with those studies, albeit preliminary, is both encouraging and disturbing. The good news is that numbers of species, in general, have remained stable over the last decade. Several species, however, apparently have experienced reduction or extinction (e.g., northern leopard frogs, longtail salamanders) or currently may be declining (e.g., slimy salamanders). In years to come, we will continue research efforts directed toward verifying these trends and identifying causes of decline.

Summary

We report here on the first two years (1994 and 1995) of a long-term amphibian monitoring program in the Cuyahoga Valley National Recreation Area (CVNRA) in northeast Ohio. Surveys of terrestrial and stream-side salamanders were conducted using transects; surveys of calling anurans were accomplished with an automated call recorder. We identified six salamander species and nine anuran species. These included one anuran, northern leopard frogs (*Rana pipiens*), that has not been found in the area for at least twenty years. Through comparisons with previous surveys conducted at least a decade ago, we identified several species that apparently have undergone decline (e.g., northern slimy salamanders [*Plethodon glutinosus*] and longtail salamanders [*Eurycea longicauda*]) and perhaps local extinction (longtail salamanders). One species (bullfrogs [*Rana catesbeiana*]) may be expanding its distribution in the CVNRA. Despite these changes among a few species, average species richness (number of species/site) has not changed in the last decade. In fact, anuran species richness may have increased somewhat, but we believe this result to be a product of more efficient sampling in the current surveys.

An additional goal of this research was to evaluate the performance of automated call recorders. Overall, we found automated recorders to be an efficient, accurate, and cost-effective method for assessing species richness and population density of calling anurans. However, we also determined that placement, species recorded, and the number of individuals calling may affect their performance. We describe procedures that may mitigate some of these problems.

Acknowledgments

We extend our appreciation to the personnel of the CVNRA for making the study possible and for contributing materially to its success: John Debo and Garee Williamson gave permission to conduct the study, Meg Benke showed us the survey sites, and Anthony Gareau helped us with site coordinates and extended permission to modify a map of the CVNRA for use in the report. Peg Bobel and the Friends of the Cuyahoga Valley Association kindly provided funds for one of the automated call recorders. Charles R. Peterson and Michael Dorcas shared with us the design of the automated call recorder and advised us on its construction and operation. We thank Bruce Stoessner and Mark Pippenger of Cleveland State University and Ned Lagrande III for assembling the automated call recorder and for other technical assistance. Finally, we thank the numerous Cleveland State graduate students and undergraduates who assisted in data collection: Lisa Botic, Ron Canterbury, Barb Catuzza, Jon Cepek, Brenda Cotter, Susanna Dzejachok, Kevin Gajda, Joann Hoty, Janet Kucner, Sheila Lewicki, Lori Mattern, Michele Oblak, Lisa Remly, Ethan Schellenberg, and the members of the 1994 and 1995 undergraduate course in ecology at Cleveland State University.